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RESPONSES OF ALEWIFE AND SMELT TO FILTERED MERCURY VAPOUR LIGHT

Report No 82-288-K

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ABSTRACT

Although alewife and smelt both showed attraction to filtered mercury vapour light, their activity patterns in response to the light source differed. Smelt oriented more readily to the light source than alewife, and were less sensitive to the higher light intensities. Behavioural adaptation to higher light intensities was noted for both species, and appeared more pronounced in smelt. A transition in behaviour occurred where both species initially responded to the light source as large groups, and later as individuals and small groups.

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To Mr. F.J. Kee
Director of Research

RESPONSES OF ALEWIFE AND SMELT TO FILTERED MERCURY VAPOUR LIGHT

INTRODUCTION

Preliminary work on the use of light as a fish attractant indicated that alewife *(Alosa pseudoharengus)* preferred shorter wavelengths of light, and tended to avoid the longer wavelengths (OHRDR 78-516-K).

Further work indicated that a filtered mercury vapour light source, which emitted primarily blue-green light, was effective in attracting alewife over a prolonged time period, thus showing promise in a fish guidance scheme (OHRDR 80-413-K). The light levels selected or preferred by alewife were, however, not determined. Little data were available on how other species which commonly impinge together with alewife, notably smelt, *(Osmerus mordax)* respond to a filtered mercury vapour light source (OHRDR 82-165-K). The objective of this study is to compare the photoresponses of both alewife and smelt to filtered mercury vapour light and to determine the light levels preferred or selected by each species over a prolonged time period.

MATERIALS AND METHODS

1. Test Animals

Adult alewife and smelt were collected with beach seines at night near Pickering GS during June and July, 1981. Alewife ranged in size from approximately 11 - 16 cm whereas smelt were somewhat smaller (8 - 11 cm). Prior to experimentation, fish were held in circular 2.4 and 3.6 m diameter tanks under a natural photoperiod and maintained on a diet of "Tetramin". Water temperature generally ranged from 11 to 13°C throughout the testing periods.

2. Spectral Composition of the Light Source

Filtered mercury vapour light was used as the sole light source during experimentation. Spectral distribution curves for mercury vapour light was determined using a Quantum Meter (QSM Model 3500, CCIW). The clear mercury vapour light produced light primarily in the ultraviolet, violet, blue, green, yellow and orange regions with noticeable peaks at approximately 430 nm (violet), 550 nm (green), and 580 nm (Yellow, Figure 1). To reduce transmitted light

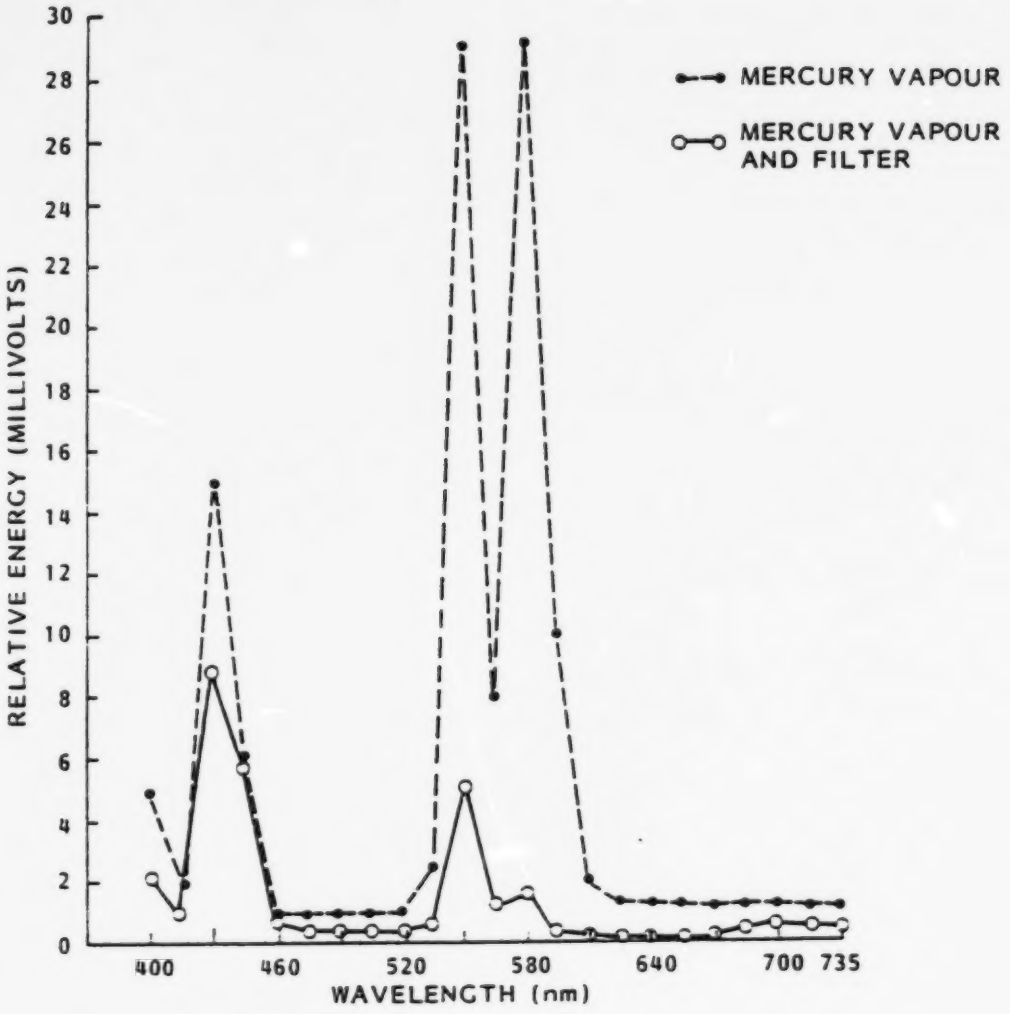

FIGURE 1

SPECTRAL DISTRIBUTION CURVE FOR MERCURY VAPOUR LIGHT
(QUANTUM METER QSM-3500)

82-288-K

in the yellow and orange regions, a blue filter was placed over the mercury vapour lamp. The filter was effective in obtaining the desired violet-blue-green wavelengths which previously had been shown to attract alewife (OHRDR 80-413-K).

3. Experimental Design

Tests were conducted under static, night-simulated conditions in a section of a large oval pool (9.1 x 4.5 m, Figure 2). Fish were allowed to acclimate in the experimental tank at least one day prior to testing. Although ambient light levels were not measurable, total darkness was not achieved. One filtered mercury vapour light source, positioned downwards at one end of the experimental runway, provided low light intensities which ranged from 80 lux ($\sim$1.6 $\mu E \cdot m^{-2} \cdot s^{-1}$) immediately under the light source to less than 0.5 lux* (<0.01 $\mu E \cdot m^{-2} \cdot s^{-1}$) at a distance of 1.8 m away from the light. Light was not measurable 2.0 m from the light source. Preliminary studies indicated that light levels exceeding 100 lux (>2.0 $\mu E \cdot m^{-2} \cdot s^{-1}$) were too high to elicit an attraction response (OHRDR 80-413-K). The experimental zone was U-shaped, which provided a refuge area removed from the light source (Figure 2).

In each experiment, 100 fish were released from their holding area (Figure 2), and their response to the filtered mercury vapour light source was monitored using closed circuit TV. Visual observations of fish in the experimental zone were also used to supplement the TV recordings. At least three replicates were performed for each species, with each replicate consisting of new fish not previously exposed to the light source. Experiments were generally 12 h in duration (1600 - 0400), and fish responses to the filtered mercury vapour light source were categorized as follows:

(i) Size and occurrence of fish groups. Observations were made on the number of individuals recorded within each aggregation or group of fish as they entered the lighted area over the monitoring period.

(ii) Number of encounters. The number of fish entering each intensity zone over a 12 h monitoring period was determined. Fish movements were monitored in only one direction (ie towards the light source) by closed circuit TV over time, with no attempt to differentiate between individual and group fish (aggregations). Active (swimming) individuals would therefore give consistently higher encounter numbers than inactive (stationary) ones. It was expected that this analysis would give a general assessment of fish activity within each intensity zone.

(iii) Intensity zone activity. Zone activity is defined as the number of individuals recorded within each intensity zone at successive 10 minute time intervals (freeze frame) over the monitoring period (15 h). Contrary to "number of encounters", zone activity does not take into account

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* estimated intensities less the 1 lux (<0.01 $\mu E \cdot m^{-2} \cdot s^{-1}$) are only approximate.

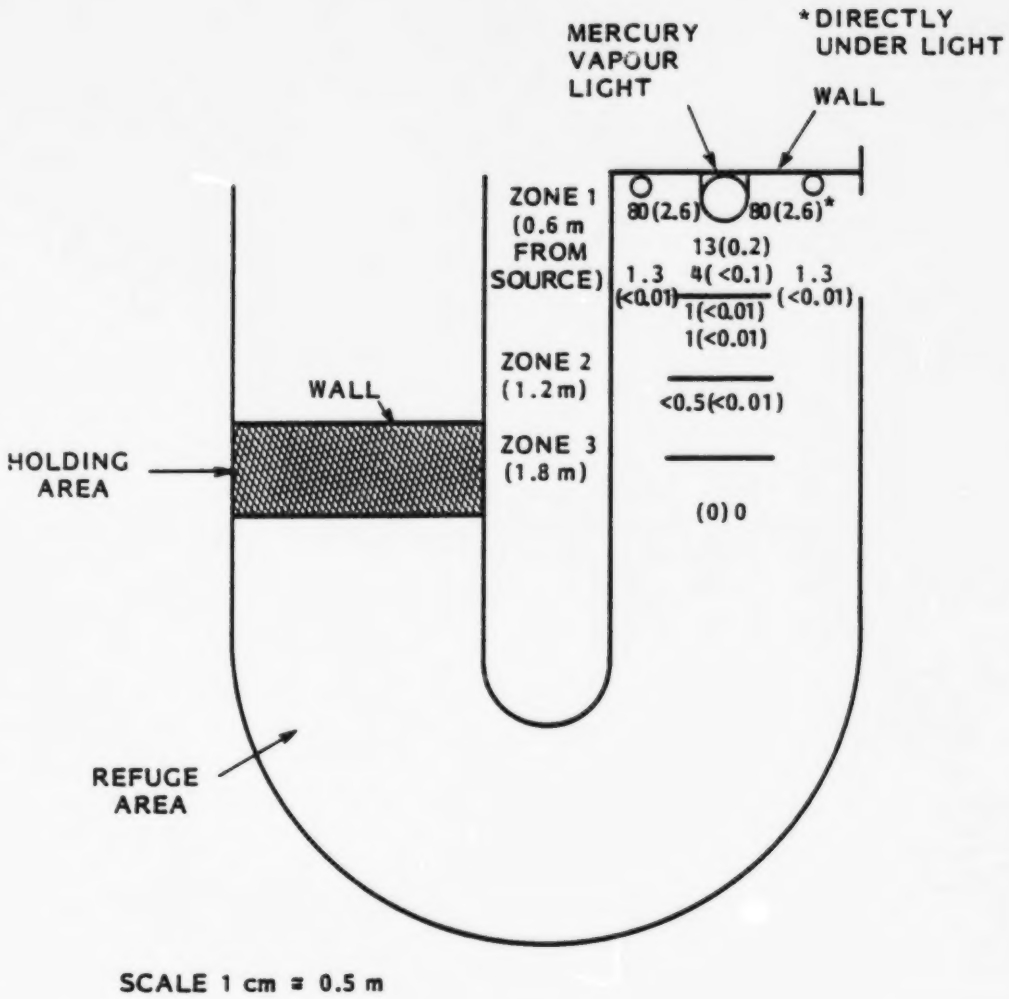

FIGURE 2

EXPERIMENTAL TANK. LIGHT INTENSITIES MEASURED AS ILLUMINANCE (LUX) AND QUANTUM FLUX ($\mu E\ m^{-2}\ .\ s^{-1}$, IN BRACKETS)

continuous movement of fish as they enter each intensity zone. An increase in zone activity would be expected if fish showed a preference for a particular intensity zone.

(iv) Duration. Information was obtained on the time spent primarily by individual fish within zones 1 and 2. Fifteen individuals were selected randomly over successive two-hour intervals throughout the 12 h monitoring period, and time spent in the lighted area was estimated. Some data were also obtained on duration of fish aggregations (groups) within the lighted area. Estimates of intensity zone activity and duration are based on only one replicate for each species. Other replicates were periodically inspected to determine whether similar patterns were evident. No major deviations were noted.

Control tests were also conducted to determine fish distribution in the experimental tank in the absence of filtered mercury vapour light. Generally, fish were distributed randomly throughout the tank.

RESULTS AND DISCUSSION

1. Size and Occurrence of Groups

Once the filtered mercury vapour light was turned on, alewife and smelt approached the light source in large groups. However, after a short time period, a transition occurred where fish ceased to form large groups, and responded to the light source largely as individuals or small groups ($n<4$). A strong positive phototaxis to the light source appeared to override the need to maintain group cohesiveness. Similarly, Wickham (1973), noted that several species ceased to form schools or large groups after being exposed to an external light source. In our tests, casual observations indicated that individual fish displayed a stronger orientation and spent longer time periods in the lighted zone than fish in large groups. Although this behavioural transition occurred for both alewife and smelt, differences between species were noted in group size, and the time period required for this transition to occur (Figure 3). Smelt group size was considerably smaller than for alewife, ranging in size from 4 to 16 fish/group with a mean group size of 8. Group cohesiveness for smelt was maintained for only a short time period (36 minutes), after which only individuals responded to the light source over a 12 h period. Average alewife group size was larger ($\bar{x} = 18$ fish, range 4 to 44), and was maintained for a longer time period (~75 minutes). After this period, individual alewife or small groups ($n<4$) responded to the light source.

2. Number of Encounters

An estimate of the mean number of fish encounters in each intensity zone over time is presented in Figure 4. Standard deviation or error bars are not presented here but are generally within 35% of the mean (Appendix A). Activity patterns (number of encounters) of fish entering each intensity zone appeared to vary for each species. Generally, for smelt, encounters in zone 1

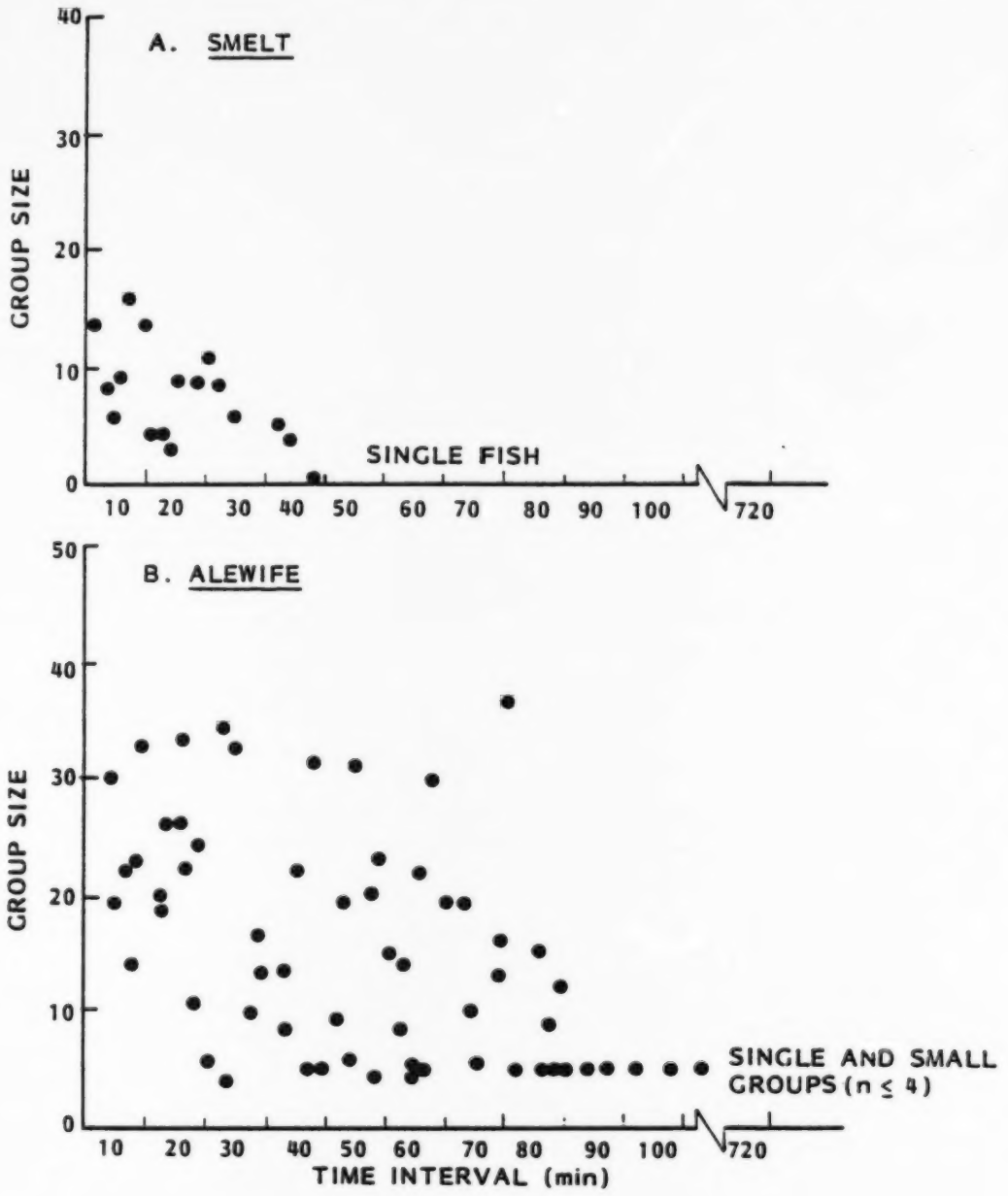

FIGURE 3

SIZE AND OCCURRENCE OF GROUPS IN RESPONSE TO MERCURY VAPOUR LIGHT (A. SMELT B. ALEWIFE)

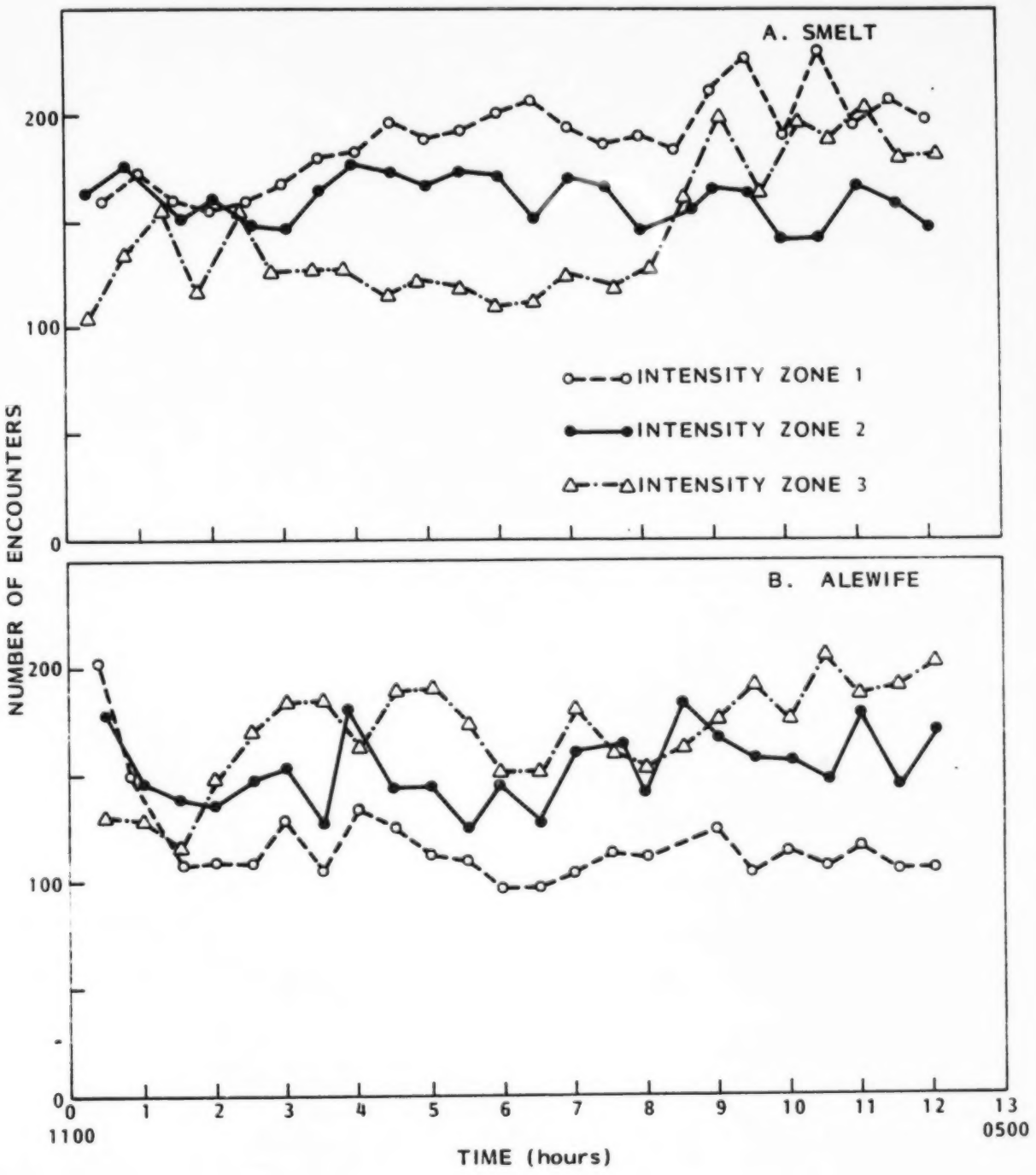

FIGURE 4

MEAN NUMBER OF FISH ENTERING INTENSITY ZONES 1, 2 AND 3 OVER THE MONITORING PERIOD

A. SMELT B. ALEWIFE

TABLE 1

MULTIPLE RANGE TEST COMPARING
MEAN NUMBER OF FISH ENTERING
INTENSITY ZONES 1, 2 and 3
OVER THE MONITORING PERIOD

Species	Ranking (lowest→ highest)			
Alewife	1	2	3	intensity zone
	4.67	4.91	5.04	number of fish (log)
Smelt	3	2	1	intensity zone
	4.79	5.01	5.19	number of fish (log)

occurred more frequently than observed in zone 3 over a 12 h period. Casual observation indicated that fish activity in zone 1 appeared highest at light levels of approximately 13 lux (~0.2 $\mu E \cdot m^{-2} \cdot s^{-1}$). In contrast, activity of alewife generally appeared higher in either zones 2 or 3 than in 1 where light levels were significantly lower (<1 lux, <0.01 $\mu E \cdot m^{-2} \cdot s^{-1}$). Although alewife entered zone 1, they spent only short time periods orienting towards the light source.

Analysis of variance (three-way) was used to compare statistically the number of encounters between species over the monitoring period, and to determine the intensity zone where most activity occurred (Appendix D). All data were log transformed to satisfy the assumption of homogeneity of variances. The F-test comparing species was significant ($F_{1,288} = 5.4$, $p < 0.05$), and indicated that activity in the lighted zones was higher for smelt than alewife. In addition, smelt response to light measured as "encounters" (movement) was probably still underestimated in zones 1 and 2, since many individuals displayed little movement, and spent longer time periods (stationary) orienting towards the light source than alewife. (Duration of fish in these zones is discussed in more detail in section 4.) The interaction term (species x intensity zone) was also significant ($F_{2,288} = 16.9$, $p<0.05$, Appendix D), indicating that trends in activity varied within each intensity zone for each species. Mean activity levels for smelt were highest for fish entering intensity zone 1, followed by intensity zones 2 and 3, which was opposite to that recorded for alewife (ie. a preference for zones 2 and 3, Table 1). For both species there was no (statistically) significant increase or decrease in activity over the 12 h monitoring period (Figure 4, $F_{23,288} = 0.1$, $p<0.05$, Appendix D). This result is however, misleading, particularly for smelt, since an increase in fish numbers in the lighted zone was noted over the monitoring period (see zone activity below). This increase in numbers was not reflected as an increase in the number of encounters, since fish spent progressively longer durations within each lighted zone, and displayed little movement (overall activity) between zones.

Although somewhat qualitative, the encounter data suggested that smelt appear more active (in terms of total encounters) than alewife in response to the light source, and also appear less sensitive to the higher light intensities. Similarly, in Lake Huron, Emery (1973) noted (field observations) that alewife were more sensitive to light (incandescent) than smelt.

3. Zone Activity

The number of individuals within each intensity zone was estimated over successive 10 minute time intervals (Figures 5 and 6). In zone 1, a substantial increase in smelt numbers occurred over time, suggesting a strong behavioural adaptation to these light levels (Figure 5). A correlation coefficient of 0.81 indicated that approximately 64% of smelt activity in zone 1 could be predicted by time. Although the correlation was poor ($r = 0.44$), a similar trend of an increase of fish numbers over time in zone 2 was also noted ($F_{1,89} = 20.8$, $p<0.05$). Activity data in zone 3 were not available for smelt.

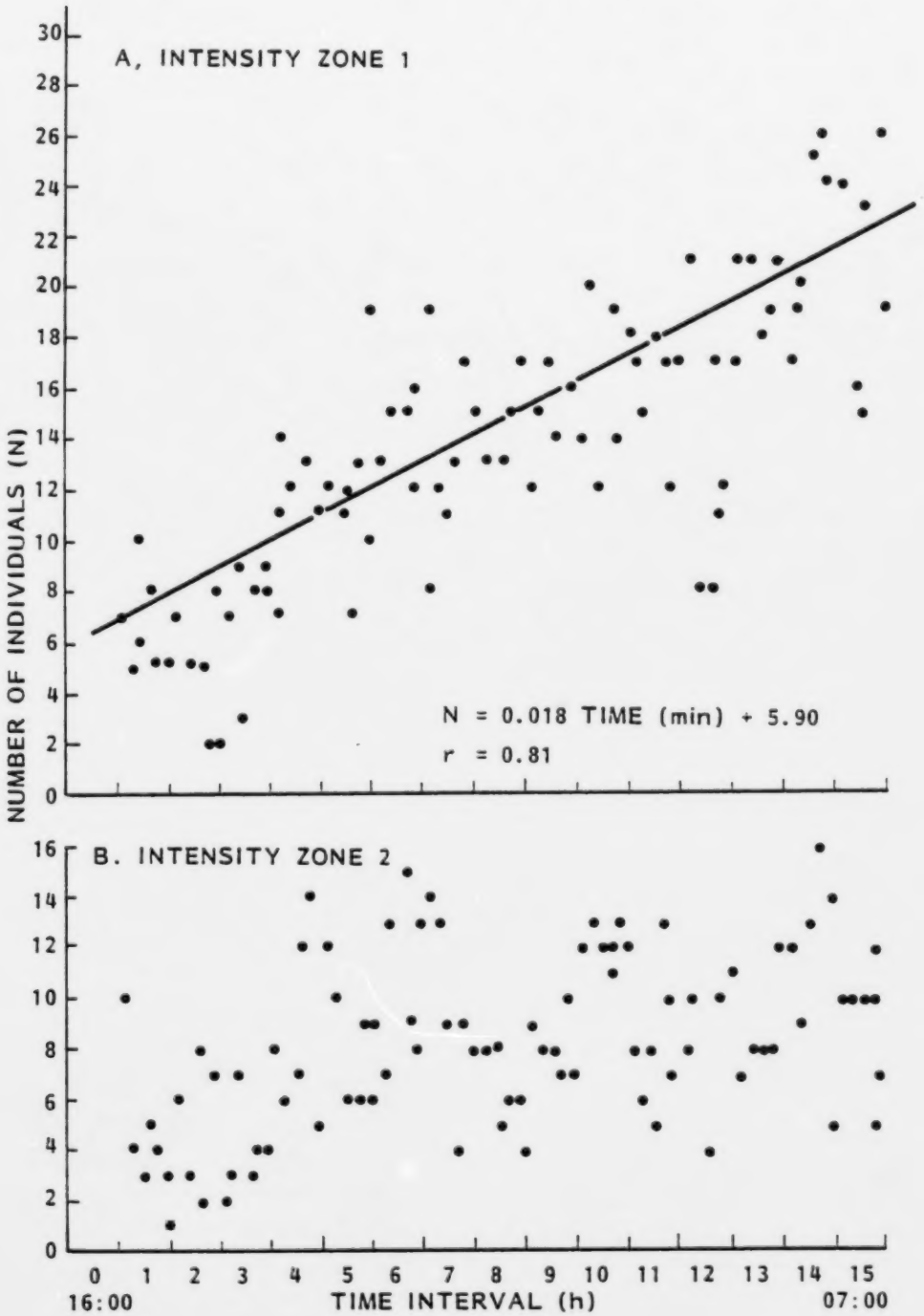

FIGURE 5

NUMBER OF SMELT RECORDED IN INTENSITY ZONES 1 AND 2

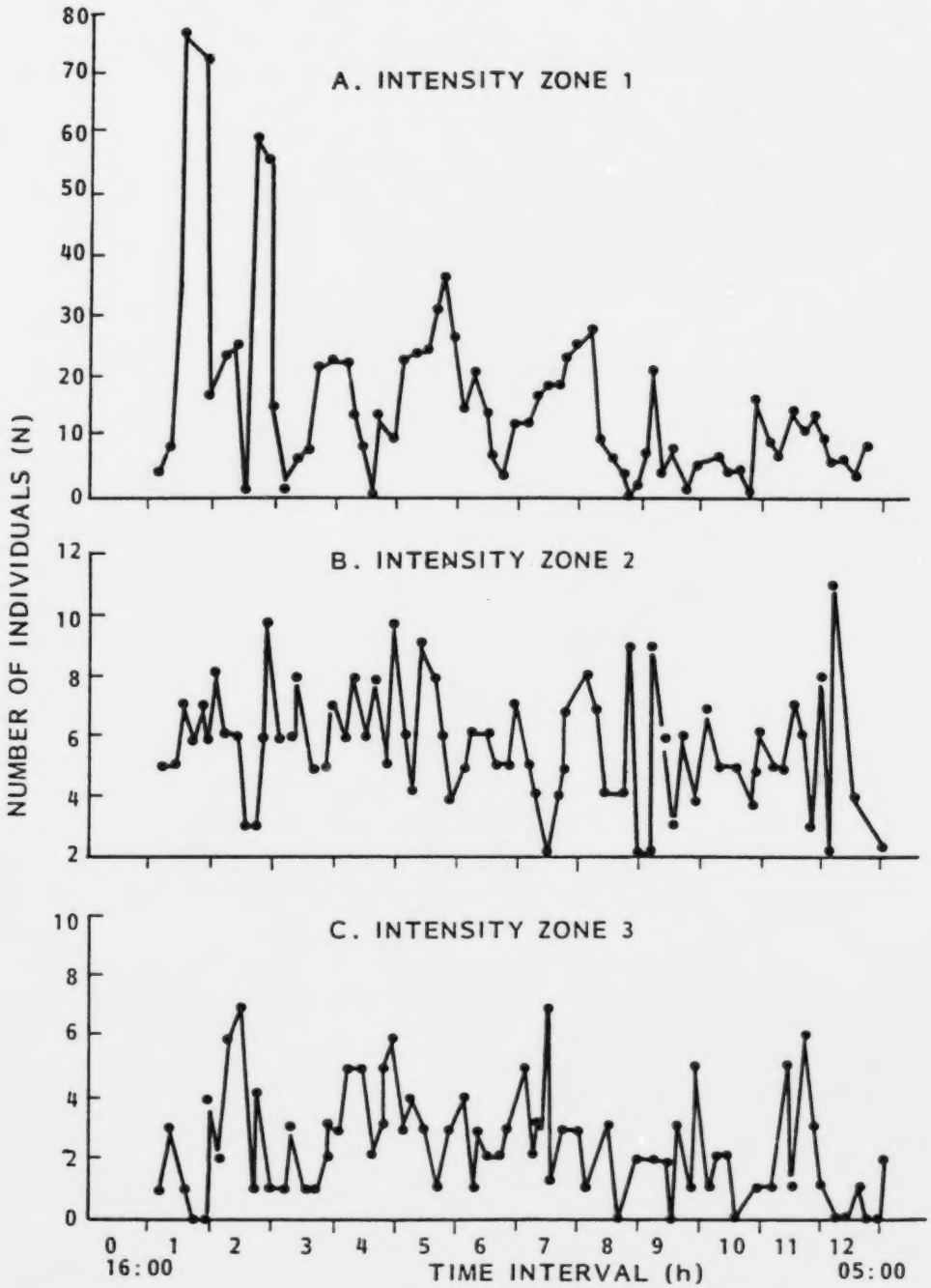

FIGURE 6

NUMBER OF ALEWIFE RECORDED IN INTENSITY ZONES 1, 2 AND 3

In contrast to smelt, there was no indication that alewife activity in zones 1, 2 or 3 increased over the monitoring period (Figure 6). This was primarily a result of fish spending only short time periods in each lighted zone. In zone 1, highest number of individuals were recorded during the initial 2 hours, which was attributed to large groups of fish entering and exiting the lighted area. A decrease in numbers (activity) over time was partly the result of the transition from large groups to small groups and/or individuals (Figure 3). Alewife spent short time periods in this intensity zone (section 4). In contrast to smelt, there were often considerable periods (several minutes) when no alewife were recorded in zone 1. No distinct positive or negative behavioural response was evident in intensity zones 2 and 3. Alewife were noted to spend more time in these zones than in zone 1 (although considerably less than smelt), resulting in a higher "number of encounters" (Figure 4). Contrary to smelt, alewife showed little evidence of adaptation to higher light levels (zone 1) over time.

4. Duration in Lighted Zone

The time spent by individual alewife and smelt in the lighted area (zones 1 and 2) varied significantly over the monitoring period (Figure 7). Mean smelt stay averaged 192 seconds, which was approximately 10 times higher than that for alewife ($\bar{x}$ = 20 seconds). This difference in duration between both species was found to be highly significant ($F_{1,140}$ = 335, $p<0.01$, Appendix D). Analysis of Variance also indicated that a significant increase in duration (time spent in lighted area) was evident for both species as the monitoring period (0-12H) progressed ($F_{4,140}$= 6.6, $p<0.05$, Appendix D). A closer inspection of the data (Figure 7) indicated that this trend was even more pronounced for smelt, with some individuals showing a noticeable increase in duration after a 2-4 h of monitoring. For alewife, a significant increase in duration was not evident until after 10 h of illumination. This increase may be related to some sort of diurnal cycle, with highest duration in the early morning (dawn). However, if a diurnal rhythm occurred, an increase in both the number of encounters (Figure 4) and in zone activity (Figure 6) would be expected. These results suggest that alewife are more sensitive to the light source than smelt, and require a longer time period for adaptation. Although behavioural adaptation was observed for both species, it occurred earlier in smelt than in alewife.

5. Light Intensities Selected or Preferred by Alewife and Smelt

Knowledge of light levels selected or preferred by each species are critical prior to implementing a light guidance scheme in the field. Although somewhat preliminary, the laboratory data suggested that highest activity for both species occurred at rather low light intensities. Smelt appear less sensitive to the light source than alewife, with highest activity generally occurring at light levels ranging from 1-13 lux (~0.02-0.2 $\mu E \cdot m^{-2} \cdot s^{-1}$)*. Strong response to these and higher levels was not evident until after a 2-4 h period. Although alewife frequently entered zone 1 (highest intensity zone) and swam directly under the light source

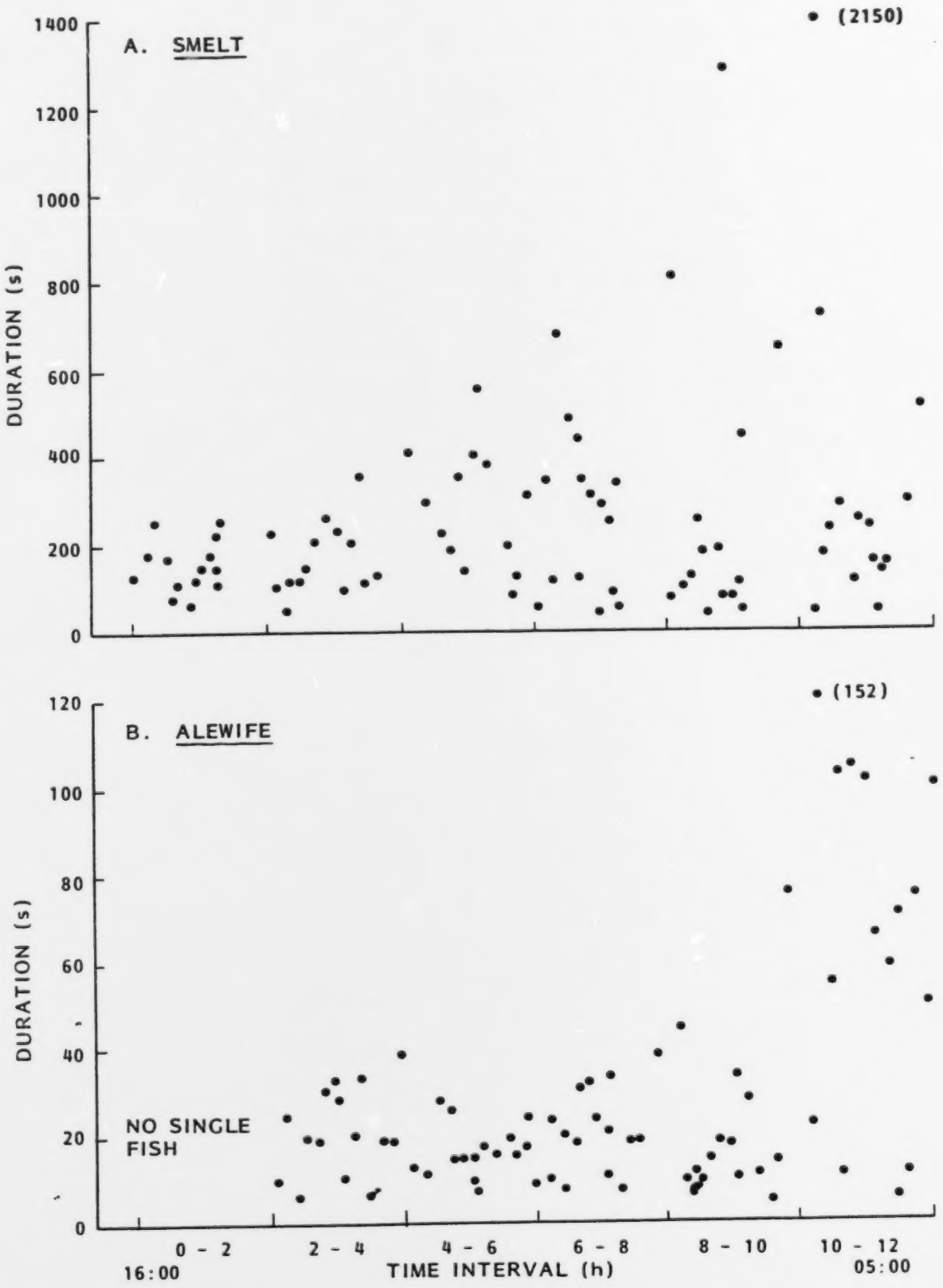

FIGURE 7

DURATION OF SINGLE FISH IN LIGHTED ZONE
A. SMELT B. ALEWIFE

82-288-K

(~80 lux, ~2.0 $\mu E \cdot m^{-2} \cdot s^{-1}$), they exited quickly, spending short time periods in the strongly lighted area. Initially, activity appeared highest at low light levels (~1.0 lux, 0.01 $\mu E \cdot m^{-2} \cdot s^{-1}$), and only after a considerable time period (~10 h) were fish noted to spend longer durations at higher intensities.

Information on the light levels required to 'hold' or maintain fish in a specific area is of particular concern when light is employed as part of a fish handling system in a forebay design. In this application, light may be used to attract fish to a fish pump thereby increasing the efficiency of a removal system. Results from this study and earlier work (OHRDR 80-413-K) suggests that low light levels, probably less than 10 lux (<0.2 $\mu E \cdot m^{-2} \cdot s^{-1}$), are required near the entrance of the fish pump to 'hold' fish (both species) prior to pumping. An adaptation period may be required before fish maintain position (longer duration) in this area; still it is difficult to extrapolate these laboratory findings to how fish behave in the field, especially since tests were conducted under static, clear water conditions. At present, the influence of water currents and/or noise created by the pump on fish behaviour is not known.

SUMMARY

1. Although alewife and smelt are attracted to filtered mercury vapour light, they displayed different activity patterns in response to the light source.

2. Smelt appeared less sensitive to the light source than alewife, and spent longer time periods in the lighted area. For both species, behavioural adaptation to the light source was evident, but appeared more pronounced in smelt.

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* Although light levels in zone 1 exceeded 13 lux (~.2 $\mu E \cdot m^{-2} \cdot s^{-1}$), casual observation indicated that fish preferred areas of this intensity.

3. Since impingement of alewife and smelt overlap to some extent (especially in the spring), data on light levels selected or preferred by each species are critical prior to implementing a light guidance scheme in the field. Results from this study suggest that highest alewife and smelt activities occur at low light intensities (<13, lux, <0.2 $\mu E \cdot m^{-2} \cdot s^{-1}$).

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APPENDIX A

Number of Fish Recorded in Lighted Zones 1, 2 and 3, Over a 12 hour Monitoring Period

1. SMELT

Time (h)	Zone 1			Zone 2			Zone 3		
	#1	#2	#3	#1	#2	#3	#1	#2	#3
0.5	157	231	88	163	235	91	144	97	99
1.0	210	149	138	193	185	126	178	100	148
1.5	209	112	148	185	123	131	172	81	213
2.0	177	97	181	200	110	152	164	39	204
2.5	185	102	172	178	114	148	135	74	259
3.0	182	96	203	168	128	151	119	75	201
3.5	193	143	181	191	118	164	117	72	205
4.0	174	182	166	169	148	222	116	70	224
4.5	178	172	221	177	99	231	118	30	223
5.0	175	145	223	159	98	229	140	48	204
5.5	164	179	241	191	103	214	139	46	202
6.0	164	206	230	158	99	232	119	57	158
6.5	179	191	240	150	131	170	121	63	150
7.0	167	204	210	183	107	214	131	70	196
7.5	160	157	234	158	84	247	132	61	183
8.0	156	190	211	167	86	185	131	47	250
8.5	162	150	226	157	73	213	141	48	306
9.0	181	187	254	149	100	243	145	60	322
9.5	175	178	315	136	106	240	102	52	288
10.0	152	160	252	147	78	206	120	53	428
10.5	156	147	337	138	67	217	109	39	415
11.0	131	173	278	159	78	245	105	42	447
11.5	175	138	296	137	89	233	136	47	344
12.0	141	169	283	126	110	195	95	53	293

Number of Fish Recorded
in Lighted Zones 1, 2 and 3
Over a 12 hour Monitoring Period

2. ALEWIFE

Time (h)	Zone 1				Zone 2				Zone 3			
	#1	#2	#3	#4*	#1	#2	#3	#4*	#1	#2	#3	#4*
0.5	212	130	263	184	219	152	191	241	117	118	188	268
1.0	148	107	790	90	98	161	185	114	120	110	192	123
1.5	117	84	173	20	81	101	231	39	86	82	190	66
2.0	100	70	204	16	88	113	213	44	102	124	218	69
2.5	108	67	193	21	105	153	189	15	148	117	234	36
3.0	120	76	208	13	99	155	207	24	154	139	235	46
3.5	115	49	168	22	86	123	194	45	152	139	248	42
4.0	114	79	219	47	144	150	221	42	163	124	180	47
4.5	97	69	216	13	79	104	255	17	191	107	268	60
5.0	102	55	199	13	83	137	219	27	187	140	237	62
5.5	67	55	224	30	76	93	226	30	148	97	260	46
6.0	72	46	174	41	103	88	258	64	121	114	224	77
6.5	55	56	201	57	60	80	174	45	122	111	245	58
7.0	70	47	202	34	108	128	236	37	125	127	273	91
7.5	109	50	223	55	153	89	233	46	142	88	265	73
8.0	88	54	224	81	141	62	217	81	134	89	261	93
8.5	116	46	337	125	155	55	314	59	153	67	283	64
9.0	93	45	257	67	142	60	296	56	187	68	275	55
9.5	69	57	198	105	115	75	276	65	142	91	337	67
10.0	94	52	215	92	118	53	288	61	120	83	304	82
10.5	64	65	214	82	97	70	277	71	145	110	364	92
11.0	87	47	226	71	119	66	332	34	119	91	351	57
11.5	87	43	196	75	118	60	250	50	111	88	372	76
12.0	39	58	216	116	105	67	289	47	141	98	367	62

* Since fish were in poor condition, these data were not included in the analysis. Similar to other replicates, highest encounters occurred in zone 3.

APPENDIX B

Zone Activity of Smelt and Alewife Over the Monitoring Period (15h)

Time (min)	Smelt		Alewife		
	Zone 1	Zone 2	Zone 1	Zone 2	Zone 3
0	7	10	0	5	0
10	5	4	4	3	1
20	6	3	8	3	3
30	10	5	36	5	1
40	8	4	76	4	0
50	7	3	73	5	4
1.0 Hr	5	1	17	4	2
10	7	6	23	6	6
20	5	3	50	4	7
30	5	8	25	4	1
40	2	2	1	1	4
50	2	7	55	1	1
2.0 Hr	8	2	59	8	1
10	7	3	56	4	3
20	9	7	47	4	1
30	3	3	56	6	1
40	8	4	14	3	2
50	8	4	0	3	3
3.0 Hr	9	8	6	5	3
10	7	6	7	4	5
20	11	7	14	6	5
30	14	12	21	4	2
40	12	14	22	6	3
50	13	7	22	3	5
4.0 Hr	11	12	13	8	6
10	12	10	8	4	3
20	11	6	10	2	4
30	7	6	12	7	3
40	13	9	10	6	1
50	10	6	22	4	2
5.0 Hr	19	9	23	2	4
10	13	7	24	3	1
20	15	13	31	4	3
30	15	15	36	4	2
40	12	9	26	3	2
50	16	8	14	3	3
6.0 Hr	8	13	20	5	5
10	19	14	14	3	2
20	12	13	6	2	3
30	11	9	3	0	1
40	13	4	12	2	7
50	17	9	16	3	3
7.0 Hr	15	8	18	5	3

Time (min)	Smelt		Alewife		
	Zone 1	Zone 2	Zone 1	Zone 2	Zone 3
10	14	8	23	6	1
20	13	8	25	5	2
30	13	5	27	2	3
40	13	6	9	2	0
50	15	4	6	7	1
8.0 Hr	17	9	4	0	2
10	12	8	0	0	2
20	15	8	1	7	2
30	17	7	7	4	0
40	14	10	21	1	3
50	16	7	3	4	1
9.0 Hr	14	12	7	2	5
10	20	13	1	5	1
20	12	12	5	3	2
30	19	12	6	3	2
40	14	11	6	2	0
50	18	13	4	3	3
10.0 Hr	17	12	4	4	1
10	15	8	0	3	1
20	18	6	7	3	1
30	12	8	10	5	5
40	17	5	7	4	6
50	17	13	13	1	3
11.0 Hr	21	10	11	6	1
10	8	7	13	0	0
20	8	8	10	9	0
30	17	10	6	4	1
40	12	4	6	2	0
50	11	10	24	1	0
12.0 Hr	17	11	48	0	2
10	21	7	-	-	-
20	21	8	-	-	-
30	18	8	-	-	-
40	19	8	-	-	-
50	21	12	-	-	-
13.0 Hr	17	12	-	-	-
10	18	9	-	-	-
20	20	13	-	-	-
30	25	16	-	-	-
40	26	14	-	-	-
50	24	5	-	-	-
14.0 Hr	24	10	-	-	-
10	29	10	-	-	-
20	16	10	-	-	-
30	15	10	-	-	-
40	23	12	-	-	-
50	19	5	-	-	-
15.0 Hr	26	7	-	-	-

APPENDIX C

Duration of Single Fish in Lighted Zones

Time Interval	SMELT Duration (seconds)	ALEWIFE Duration (seconds)
0-2 hr	140 125 178 150 260 183 176 233 106 110 56 72 250 152 145	- - - - - - - no single fish
2-4 hr	220 242 104 96 56 207 113 124 117 364 139 128 209 99 266	4 7 18 10 26 10 6 15 9 22 8 6 20 34
4-6 hr	420 408 71 570 270 384 67 183 221 85 191 124 368 305 143	13 17 11 16 28 19 27 17 15 18 15 23 15 9 7
6-8 hr	56 318 344 29 129 287 677 258 474 94 128 69 448 348 347	10 11 24 21 7 34 20 7 19 19 31 19 33 39

APPENDIX C (Cont'd)

Duration of Single Fish in Lighted Zones

Time Interval	SMELT Duration (seconds)		ALEWIFE Duration (seconds)	
8-10 hr	72	78	10	10
	807	77	45	33
	103	1219	10	28
	122	112	12	11
	249	61	10	5
	185	453	14	14
	47	644	19	76
	182		18	
10-12 hr	3150	248	152	59
	62	162	23	71
	727	64	113	6
	174	146	57	12
	231	155	116	75
	295	289	12	50
	123	539	106	100
	255		66	

APPENDIX D

ANOVA (three-way) COMPARING ACTIVITY BETWEEN ALEWIFE AND SMELT IN RESPONSE TO FILTERED MERCURY VAPOUR LIGHT

Source	d.f.	F-test
species	1	5.4*
time	23	0.1
intensity zone	2	0.2
species x time	23	0.2
species x intensity zone	2	16.9*
time x intensity zone	46	0.1
species x time x intensity zone	46	0.2
total	431	

* $p<0.05$

APPENDIX E

ANOVA (two-way) COMPARING DURATION OF SMELT AND ALEWIFE IN THE LIGHTED AREA

Source	d.f.	F-test
Duration	1	335**
Illumination Period	4	6.6*
Duration x Illumination Period	4	2.1
Total	149	

* sig $p<0.05$
** sig $p<0.01$